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# Healthy adult aging and decision-making: Is it all downhill from here?

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## **ABSTRACT**

As we age there are significant changes to our brain structure and cognitive functioning. There is a substantial body of literature exploring changes to memory and attention during healthy adult aging. There has been considerably less focus on the impact of aging on other areas of cognition, specifically, decision-making. This is surprising given that choices are ubiquitous in daily life across the lifespan. For example, older adults still face many significant decisions including those concerning finances in light of reduced income and choices about lifestyle factors in response to potential healthcare issues. Recently, the research community has increasingly shown appreciation of these issues and the literature on changes to decision-making function due to healthy aging is beginning to converge on key themes that are particularly telling in terms of how aging affects decision-making. The literature has focused predominantly on the negative effects of healthy aging on decision-making, particularly in terms of risk-processing. However, although fewer in number, some studies have identified age-related positive effects commonly attributed to an accumulation of 'wisdom' by the older adult. This review will provide an overview of the negative and positive changes to decision-making as we age and will, uniquely, converge these two streams of research and put forward the hypothesis that age-related changes in decision-making, underpinned by changes to the structure and function of the aging brain, underlie both positive and negative changes, the manifestation of which depends on choice context.

## **HEALTHY ADULT AGING AND DECISION-MAKING: IS IT ALL DOWNHILL FROM HERE?**

The stereotypical view of the older adult as one who experiences global declines in cognitive and physiological functioning is pervasive. However, experimental research has provided evidence that healthy aging is associated with an “orchestration” of positive and negative physical and mental changes (Richards & Hatch, 2011). Some of these changes are well-documented, for example, consider the vast amount of research that has investigated changes in memory and attention during healthy aging (these fields are not the focus of this review; for comprehensive reviews in these areas, see Cansino, 2007; Nyberg, Lövdén, Riklund, Lindenberger & Bäckman, 2012), while other cognitive processes in which age-related changes are apparent have been explored to a significantly lesser extent. Age-related change in decision-making functioning is one of these lesser explored areas, which is surprising given that decision-making is ubiquitous in our everyday lives. There are a number of behavioural studies that have investigated age-related changes in some of the domains in which decisions are made. Recently, neuroimaging has been used to identify the functioning of brain areas associated with decision-making, although these articles are few in number. The experimental cognitive approach taken by these studies has the power to identify which particular cognitive mechanisms show age-related disruption and thus where the attention of those interested in age-related changes in decision-making should be directed. For example, when constructing the most efficacious decision aids for older adults these should target those areas of cognition where there is a strong evidence base for decreased functioning. It is therefore important to build upon the research that has already been conducted in

order to build a more complete picture of the nature of age-related changes in decision-making, a process upon which this review will focus.

The number of older adults within the population is increasing and this trend is forecasted to continue. According to a report from the United Nations on the distribution of age ranges worldwide, in 1950 1-in-20 individuals were aged 65 or over; in 2000 this ratio had changed to 1-in-14 and by 2050 this ratio is forecasted to be 1-in-6 (United Nations Population Division, 2002). This change will be associated with increased pressure on older adults to manage their own finances and quality of life in addition to maintaining a longer work-life due to lengthier life spans. Given this increasing pressure on older adults, retaining a high level of decision-making functioning is of extreme importance for the well-being of the older adult in addition to society as a whole. It is worthwhile noting that an older adult is defined in this case as being over 65 years of age but this definition is not universal. A detailed discussion of the boundaries that have been used in the literature is included later in this section.

Research has uncovered that there are age-related declines in cognitive functioning (Sternthal & Bonezzi, 2009). These declines lead to real-world consequences for the older adult. Financial decision-making is one such area where a decline in functioning has been noted (Kasten & Kasten, 2011; Weierich et al., 2011). In a study investigating investment decisions older adults made on average 3-5% lower returns than younger adults due to risk aversive choice strategies and the spreading of investments over a broader range of options (Korniotis & Kumar, 2009; Bellante & Green, 2004). The ability to make financial decisions, defined as a maximisation of cost-benefit trade-offs in credit transactions, has been posited to follow a U-shaped trend peaking at 53 years of age (Agarwal, Gabaix, Driscoll &

Laibson, 2009) although, as will be seen throughout this review, this proposed window of peak performance does not hold for all choice domains. Furthermore, choices about health-related outcomes (such as treatment plans for health-related issues) suffer from age-related declines with older adults choosing relatively less optimal outcomes that would result in greater monetary loss and/or a decrease in the utility of the option (Boyle et al., 2012).

Declines in decision-making performance have been linked to processes such as degraded processing speed (Löckenhoff, 2011), decreased information sampling or an increase in the use of heuristics, or cognitive “shortcuts” (Hanoch, Wood & Rice, 2007), or changes in the processing of probability and value (Weller, Levin & Denburg, 2011). Another potential contributory factor for less efficacious choice behaviour in the aforementioned domain is the tendency for older adults to focus more on emotionally positive compared to negative information (Carstensen & Mikels, 2005). This “positivity effect” is prevalent within the literature investigating decision-making in older adults. The positivity effect is based upon socioemotional selectivity theory and posits that as one becomes older, and perception of available time becomes bounded, one’s motivation to achieve more subjectively meaningful goals, such as creating and maintaining intimate relationships and feelings of interconnectedness, increases. This is in comparison to younger adults who perceive available time as more expansive and are more motivated to achieve goals that are associated with novelty and the acquisition of information (for a review, see Carstensen & Mikels, 2005). When making a decision older adults tend to sample more positive information compared to negative information while younger adults tend to sample from both types (Löckenhoff & Carstensen, 2007). When reporting strategies behind information sampling, older adults tend to report strategies that

maximise positive emotions while younger adults tend to report strategies that avoid negative emotions (Chen & Ma, 2009). This loss-avoiding decision approach means that losses are not fully integrated into decision frameworks and thus, when losses are critical considerations, decision-making performance suffers (Chen & Ma, 2009). The positivity effect has complex effects upon decision-making which will be returned to throughout this review.

Changes to cognitive processes as detailed in the previous paragraph have been associated with age-related reductions in brain mass (Good et al., 2001; Raz et al., 2005; Resnick, Pham, Kraut, Zonderman & Davatzikos, 2003). Many of the brain areas commonly associated with decision-making are those most severely affected by age-related neural atrophy, notably lateral frontal and parietal areas in addition to subcortical regions, which results in reduced functioning within these areas as described by the frontal hypothesis (Dempster, 1992; West, 1996), HAROLD model (Cabeza, 2002) and dopamine hypothesis of cognitive aging (Braver & Barch, 2002). It is therefore unsurprising that neurobiological changes associated with healthy aging have been associated with age-related changes in decision-making strategies, and thus investigation of how healthy age-related neurobiological changes are associated with declining decision-making function are of value for their ability to elucidate causal factors of sub-optimal behaviour.

When considering the research investigating age-related effects on decision-making, it is important to consider the samples being studied. Terms such as “older adult” are broad and open to different interpretations. Some studies have defined their older group as being over 50 years of age while others have provided samples with a minimum age of approximately 65. Although testing of such ages within the definition of “older adults” may appear valid, comparison may be fraught with

confounds. The difference in lifestyle between a 55 year old and 65 year old may be markedly different, for example, one may be in full-time employment whereas the other may not. There may also be different societal influences given the differences in the time period in which they grew up (this potential issue applies when comparing performance across any age range). Work is now beginning to emerge in which different cohorts are defined more clearly, for example, the definition of the “oldest-old” as those of 85 years of age and above (of which we know very little in terms of decision-making functioning) helps by providing some clear age boundaries. One must also take into account other differences between younger and older groups in any study which performs contrasts between them. There are studies in which younger adults are university students but older adults are from a community sample, thus we are arguably testing a group of high-functioning younger individuals with a broader range of community dwellers. Furthermore, in some studies the older adults are (at the time of testing) university academics, thus may not be representative of the wider older adult population. Care must be taken in future studies to maintain a balance between comparative groups for inferences to be made that are not contaminated by such confounds. In order to aid the reader in helping them determine the possible effects of such confounds within the literature, where single studies are used to provide inferences the mean ages, standard deviations/range of scores and source of the groups (US = university sample, CD = Community dwellers) will be provided wherever possible.

This review will explore empirical findings as to the functioning of decision-making capability in older adults. Firstly, domains in which decision-making functioning seems to increase, or be maintained, will be described and, following this, areas in which marked declines in decision-making quality are evident will be



covered. This review will maintain a focus on cognitive and emotional processes that underlie the changes in decision-making functioning with the aim of identifying common themes within the emerging literature thus providing targets for future basic and applied work.

### **It's not all bad: Age-related positive associations with decision-making functioning**

It is of great importance to not only find valid empirical evidence for age-related declines in decision-making ability but to also highlight those domains in which there are age-related increases in, or maintenance of, functioning. Identifying these domains will greatly aid in designing environments in which older decision-makers can make decisions of greater utility or compensate for declines in decision-making functioning.

A key theme that will be put forward throughout this review is that the same cognitive and emotional mechanisms that underlie negative age-related effects on decision-making also underlie positive effects. Furthermore, it will also be put forward that these positive and negative changes are associated with changes within the same brain regions within the neural system for decision-making. The positivity effect (as described above) has been linked to decreased optimality of choice behaviour in some domains if in those domains consideration of losses is important. However, as we will soon see, the positivity effect also provides a resistance against some well-known choice fallacies.

Although many cognitive skills decline with age, older adults make better decisions, compared to younger adults, in many choices of which they are familiar,

and thus within which they have acquired wisdom. In a task in which older ( $M = 68.2$  years,  $SD = 6.8$  years, CD) and younger ( $M = 20.8$  years,  $SD = 5.3$  years, US) individuals had to choose between a certain payout and a risky payout (of which the contingencies of the latter had to be learnt through repeated sampling), older adults showed similar levels of adaptive decision-making to younger adults despite older adults sampling less information about the risky option (Spaniol and Wegier, 2012). Reduced sampling by older vs. younger adults has been measured across many decision-making domains (for a review, see Mata and Nunes, 2010). The dopamine hypothesis of cognitive aging (e.g. Li, Lindenberger & Silk, 2001) posits that degradation in ascending dopaminergic function leads to “neural noise” within dopaminergic signalling within ventral striatal and ventromedial prefrontal regions. Dopaminergic activity within these regions has been associated with several decision-making processes including reward processing (Delgado, 2007), motivation and approach-avoidance (McClure, Daw & Montague, 2003), coding of risk and uncertainty (Fiorillo, Tobler & Schultz, 2003) and stimulus-response learning (Delgado, Li, Schiller & Phelps, 2008). Age-related degradation in dopaminergic functioning should be associated with decreases in the performance of all these processes and can explain reduced sampling; however, in this instance, despite decreased motivation to sample, decision-making performance was seemingly not affected. Further work to explore the reasons behind such an apparent discrepancy is required; however, it may be that older adults may have been using a “tried-and-tested” strategy based upon their increased practice in making decisions that masked any degradation in neural functioning.

Older adults also seem not to be as affected by irrelevant distracters when making decisions. The *decoy effect* is a phenomenon in which inserting an irrelevant

option within a choice (i.e. one that would never be chosen) causes a reversal in the choice made, typically ending with the chooser preferring the option that provides lesser utility. Older (60-89 years, CD) and younger (17-27 years, US) individuals indicated a preference between three activities offering varying amounts of course credit that took differing amounts of time to complete or between three store discount cards that varied in the level of discount and minimum purchase required to acquire the discount (Kim and Hasher, 2005). Younger adults were affected by the decoy when making choices about discount cards, but not when choosing between activities for course credit. In contrast, across both domains, older adults' decisions were typically not affected by decoys (Kim and Hasher, 2005). Younger individuals reported as much knowledge about discount cards and course credit whereas older adults expressed greater knowledge about discount cards compared to course credits; therefore, domain-specific knowledge was posited not to be the reason behind the discrepancy in choice regularity. However, younger adults expressed an interest in course credit but not discount cards whereas older adults expressed interest in both, thus tentatively suggesting that engagement in the choice may be an underlying factor in resistance to the decoy effect. However, it is worth noting that the decoy always offered an equal discount or credit value to one of the other choices but involved spending drastically more time or spending more money. Therefore, it has been suggested that older adults may be more resistant to excessive spending in terms of money and effort (Tentori, Osherson, Hasher and May, 2001), thus the decoy is immediately ignored as it is over a threshold defined by one's own financial/mental/physical "budget". One other explanation is that due to reduced dopaminergic functioning older adults sample less, thus resistance to the

decoy effect may occur due to heavy discounting of the decoy as only the most subjectively important options are included in the set of options being considered.

In addition to the decoy effect, older adults are more resistant to another well-known bias within decision-making, the sunk-cost fallacy. The sunk-cost fallacy occurs when the chooser, instead of cutting their losses, selects to continue to invest in a course of action in which a prior investment has been made, e.g. the tendency to continue to watch a boring movie you have paid to see compared to one that was free. Older adults' resistance to the sunk-cost effect has been found in several studies and thus this finding seems reliable (Strough, Mehta, McFall and Schuller, 2008; Strough, Karns and Schlosnagle, 2011; Strough, Shlosnagle and Didonato, 2011). This resistance has been attributed to the positivity effect whereby the prior investment (which can be classified as a loss as it involved a loss of money, effort, etc.) is heavily discounted with the decision-making framework and therefore does not impinge upon the older adult's drive to acquire positive outcomes, an optimal solution in this case. It is also worth noting that in older and younger adults that do fall foul of the sunk-cost effect, simple decision aids (such as instructions to "think like a scientist") reduce levels of the bias equally across both age ranges (Thomas & Millar, 2012) tentatively suggesting that degradations in decision-making quality in older adults may be easily reversible with simple interventions. Thus, it may be the case that degradations in decision-making functioning are not lost, but that compensation for them demands cued higher-order processes to override non-optimal (semi-) automatic decisions strategies. However, significantly more research is required using various decisions aids in a wide range of choice environments to produce more substantial validation of this hypothesis.

Given the evidence for age-related decreases in cognitive ability it would seem sensible that choice scenarios containing multiple options each with several attributes would pose a problem for older decision-makers. However, emerging evidence suggests that, in certain cases, this may not be the case. Even when choice complexity is increased by enlarging the number of attributes and choices, older adults (65-84 years, CD), middle-aged (45-64 years, CD) and younger (25-44 years, CD) adults tend to adapt their decision-making strategies in the same manner (Queen, Hess, Ennis, Dowd and Grühn, 2012) although this is not universal (Wood et al., 2011) which will be discussed in the next section on age-related negative effects on decision-making. Given the evidence so far for reduced sampling in older adults (Johnson, 1990) this result at first appears incongruous. However, older adults have been found to be as adaptive as younger adults when it comes to adjusting information-search strategies (Hess, Queen & Ennis, 2013; Mata, Schooler and Rieskamp, 2007). In addition, these types of tasks (e.g. purchasing an automobile) provide more realistic simulations of everyday choices as opposed to lab-specific scenarios. Older adults have been found to perform better than younger adults on decision-making tasks that more accurately represent real-life events (Worthy, Gorlick, Pacheco, Schnyer and Maddox, 2011; Worthy and Maddox, 2012). Older adults have been found to select more highly-rewarding options when choices that they make impact upon subsequent choices (*choice-dependent* task) and optimal performance depends on an efficacious learning strategy (as would happen in real-life) rather than in “one-shot” situations where all choices are independent (*choice-independent*). In contrast, younger adults show the opposite pattern (Worthy, Gorlick, Pacheco, Schnyer and Maddox, 2011; Worthy and Maddox, 2012).

The difference in choice behaviour between older and younger adults witnessed in this task has been posited to be due to the heuristic used to determine choice strategy. Older adults have been found to prefer a simpler *win-stay-lose-shift* (WSLS) heuristic where choice only shifts to an alternative option if the selected option proffers a loss; if the option pays out a win then choice remains on the previously selected option (e.g. Frank and Kong, 2008). Younger adults tended to utilise a *reinforcement-learning* (RL) approach. The RL approach is algorithmic (i.e. non-heuristic) and based upon calculation and comparison of expected reward values of each outcome. The WSLS and RL models each offer the better strategy in the choice-independent and choice-dependent tasks respectively. Thus, in this instance, the favouring of the simpler heuristic by the older adults, which is likely due to decreased cognitive resources underpinned by decreases in neural function, actually works in favour for the older adult. However, in tasks that require learning in which a WSLS strategy is not appropriate, older adults' performance is typically worse compared to that of young adults (this will be covered in the next section). Furthermore, if the individual is faced with social pressure to perform well (i.e. winnings for the participant and that of another depends solely on the participant's making gainful decisions), older adult's performance (average age 67.4 years, CS) decreases below that of younger adults' (average age 20.65 years, US) which has been attributed to the unavailability of additional frontal resources in the brain within older adults to compensate for the additional cognitive load caused by the social pressure (Cooper, Worthy, Gorlick & Maddox, 2013). Findings such as these have wide applicability to real-world decisions in which decisions are inextricably linked with varying levels of stress. Further work exploring the effects of stress or similar

events that increase cognitive load is needed in order to permit a greater understanding into this important area of research.

To summarise, it is known that there are age-related declines in neural and cognitive processing. These declines affect the quality of decision-making in older adults. However, there is enough evidence to posit that the same mechanisms that underlie negative effects on decision-making (which we will move onto in the next section) also underlie many positive changes, but only in certain domains. Further work needs to occur based upon the theory posited herein which further explores domains in which older adults become more proficient decision-makers. This would have a multitude of applications such as framing decision-making scenarios (such as choices involving healthcare or financial outcomes) such that older adults can use their decision-making abilities fully.

### **The ‘downside’: Age-related negative associations with decision-making functioning**

Although, as can be seen in the previous section, there has been some research into age-related positive effects on decision-making, the majority of the literature has explored negative effects. There are themes emerging that have identified certain domains in which healthy older adults choose outcomes with poorer utility compared to younger adults. This section will review the literature on age-related negative effects on decision-making and identify the emerging themes.

Dual-process theorists propose that any instances of choice in our everyday lives involve the use of deliberative strategies or an affective approach in which we use our “gut feelings” (for a review see Evans, 2008). Reliable evidence indicates

that when the optimal solution is to use an affective strategy, older adults' decision-making performance is similar to that of younger adults. In contrast, when a deliberative strategy is optimal, younger adults make considerably better decisions (typically measured in terms of financial gain) than older adults (Hess, Queen & Patterson, 2012; Huang, Wood, Berger & Hanoch, 2013; Mikels, Cheung, Cone & Gilovich, 2013; Queen & Hess, 2010). Age-related degradation in performance when utilising the latter type of decision strategies has been linked to the progressive atrophy during healthy aging of cortical brain regions involved in deliberative, cognitive, processing (Braver & West, 2008). Older adults' decision times are significantly longer than those measured in younger adults (for a review, see Löckenhoff, 2011) which, at first glance, could be viewed as a compensatory method for degradation in deliberative ability. Adults over 70 years of age show decision speeds approximately 1.5 times longer than individuals in their twenties (Myerson, Robertson & Hale, 2007). However, given the reliable findings showing age-related degradation in deliberative processing, this suggests a general slowing of decision-making function rather than a compensatory method.

One area which has received a relatively greater amount of attention has been in decisions involving risk. Within this area domain-specific age-related changes have reliably been observed. In tasks in which a risk-averse strategy is the optimal course older adults tend to be more risk-seeking than younger adults leading to decreased gains (Heninger, Madden and Huettel, 2010; Zamarian, Sinz, Bonatti, Gamboz and Delazer, 2008). Almost entirely, this understanding comes from use of the Iowa gambling task, or IGT (Bechara, Damasio, Damasio & Anderson, 1994). In the IGT participants are tasked with making as much (hypothetical) money as they can. They are faced with four decks of cards of which the cards are face down so



have to be flipped over to be read. Each card carries a monetary reward and, potentially, a monetary punishment. Two decks provide high magnitudes of reward but are constructed so that they will eventually lead to an overall loss. In contrast the remaining two decks offer smaller rewards but are constructed in a way that they will lead to an overall gain. Thus, the participant must, over multiple choices, learn the contingencies of the decks and inhibit impulsive drives to pick the cards with the higher rewards, instead, opting to play the “long game”. There are several studies indicating that older adults perform significantly worse than younger adults on the IGT (Bauer et al., 2013; Denburg, Tranel & Bechara, 2005; Denburg et al., 2009; Fein, McGillivray & Finn, 2007; Isella et al., 2008; Lamar & Resnick, 2004; Mohr, Li & Heekeren, 2010; Zamarian, Sinz, Bonatti, Gamboz & Delazer, 2008). This appears to contrast with previous work suggesting that older adults employ useful heuristics (i.e. win-stay lose-shift) when faced with tasks that require learning of contingencies (Worthy et al. 2011; Worthy and Maddox, 2012). However, as opposed to these tasks, use of the WSLS strategy in the IGT would lead the individual to maintain choice on higher-rewarding decks, thus leading to significant loss.

Performance degradation in the IGT does not occur in all older adults (Denburg et al., 2005; Wood, Bussemeyer, Koling, Cox & Davis, 2005); however, it is more common to generally find age-related decreases in performance. Degradation in IGT performance has been attributed to decreased executive functioning and memory functioning (Brand and Schrieber, 2013; Denburg et al., 2005; Fein et al., 2007; Isella et al., 2008) which is associated with impaired learning ability leading to a predominantly reward-focused strategy as the immediate impact of the rewards is more salient than future outcomes. Neurobiological underpinnings for this reward-driven focus in older adults have been provided. Neural activity in the striatum, an

area involved in the indexing of subjective value of rewards, is equal in older and younger subjects when anticipating a monetary reward. In contrast, when anticipating a loss, older adults express significantly less activity in this area compared to younger individuals suggesting that losses are integrated into decision-making strategies to a much lesser extent in older compared to younger individuals (Samanez-Larkin et al., 2007), thus susceptibility to acquiring an overall loss in the IGT is due to decreased integration of the potential punishments into current decision frameworks. Such age-related changes may also underlie the positivity effect as it appears that losses are less involved in decision strategies at a biological level.

There is some debate as to whether such age-related performance degradations are approximately linear. IGT performance has been found to begin decreasing after (approximately) 35 years of age (Fein et al., 2007) while, in contrast, middle-aged individuals (40-59 years) have been found to perform in a similar way to younger individuals (20-38 years) but both significantly better than older (61-80 years) adults (MacPherson, Phillips & Della Salla, 2002). The age at which cognitive decline begins has been associated with a great deal of debate (Park et al., 2002; Salthouse, 1996). With this in mind, the general timeline for age-related degradation in decision-making functioning needs to be made clear so that it is known at which age groups particular attention, and use of decision aids, should be targeted.

When the task calls for a risk-seeking strategy older adults tend to perform as well as younger adults (Dror, Katona and Mangur, 1998; Mather et al., 2012; Westbrook, Martins, Yarkoni and Braver, 2012) although it is important to note that within the literature the tasks in which risk-seeking was the appropriate strategy have

also provided well-defined risks, the opposite of which was true for the tasks calling for a risk-averse strategy. When faced with choices involving risk, older adults have reliably been shown to perform at an equal level to younger adults if the risks are well-defined but express comparatively poorer performance when faced with ill-defined risks (for a recent meta-analysis see Mata, Josef, Samanez-Larkin and Hetwig, 2011). This has been related to age-related functional decline of fluid intelligence (the ability to reason) linked to age-related cortical atrophy. However, tasks involving well-defined risks in which decisions do not rely on fluid intelligence, instead relying on crystallised intelligence (knowledge of previously encoded knowledge and skills), do not suffer (Bruine de Bruin, Parker and Fischhoff, 2012; Li, Baldassi, Johnson & Weber, 2013). Further work needs to be carried out to pull apart the effects of risk definition and risk strategy to come to a conclusion as to how age is related to changes in strategy involving decisions under risk. This will impact upon a multitude of real-world domains, e.g. older adults' strategy towards financial risk or risks linked to healthcare.

The decision tasks described so far within this section have focused on lab tasks designed to measure particular sub-processes within everyday decision-making. Choices in our day-to-day lives are typically more complex. Multi-attribute choice tasks have been used in order to gather data about decision-making performance in situations that more closely mimic the complexity of particular everyday decisions, such as shopping. Such tasks involve the participant choosing one of several items that vary in quality on several attributes, for example, one may be creating a preference from a list of 5 types of coffee based on 5 attributes, such as strength, price, popularity and so forth. There has been much interest in age-related changes in performance in multi-attribute tasks given that such choices

feature heavily in our lives and some forms have enormous implications for ourselves and others, e.g. selecting a treatment option from several available. Given that they are designed to mimic certain everyday choice scenarios, that older adults have greater experience in such environments than younger adults, and that tasks that engage older individuals tend not to be associated with decreases in decision-making performance (Castel, 2005), it could be reasonable to hypothesise that age-related degradation in decision quality may not appear in these tasks, especially in light of the findings of Queen et al. (2012) in which older adults were found to be as adaptive in their decision-making strategies as younger adults; however, this seems not to be the case universally.

There has been particular interest in age-related changes in a type of multi-attribute task, namely that of choosing between healthcare plans. There is commonly an abundance of such plans available and selecting an appropriate plan can be a significantly important choice. Given health-related issues within the older population, exploring how these individuals choose suitable plans for themselves is, understandably, deserving of attention. Older adults have been reliably found to be at greater risk of selecting a non-optimal solution for their particular needs compared to younger individuals (Finucane et al., 2002; Finucane & Gullion, 2010) and older adults tend to show more comprehension errors and express more inconsistent preferences across different frames (Finucane et al., 2002); therefore, it is important to explore decision-making function in choice domains pertinent to the older population, such as choosing between healthcare plans, as individual choices can have significant influence on the individual's and others' wellbeing.

In the U.S., a particular change in policy attracted attention in relation to this field of decision-making, namely the Medicare Modernisation Act of 2003, also

known as Medicare Part D. Medicare Part D permits older adults to obtain subsidies on their medical prescriptions. The number of alternatives is typically large with an average number of 35 options across US states (Kaiser Family Foundation, 2014). Given the number of alternatives combined with differences between plans in the types of drugs included, the formulary of the drug included within the plan and the associated premiums, the choice is complex. It has been found that when faced with these types of choices, older adults more often select sub-optimal plans, or even opt-out altogether, compared to younger adults (Hanoch, Wood, Barnes, Liu & Rice, 2011; Szrek & Bundorf, 2011; Wood et al., 2011). Typical experimental studies provide less than ten alternatives; however notable age-related effects have been found even with this lesser amount of alternatives compared to the full Medicare Part D. Notably, increasing the set of alternatives has a greater negative impact on decision-quality in older adults vs. younger adults (Wood et al., 2011). The effect of increasing the number of alternatives within a choice has been reliably found to have a greater negative effect on decision quality in older vs. younger adults and older adults report greater aversion to increasing set size compared to younger adults (Mikels, Reed & Simon, 2009; Reed, Mikels & Simon, 2008) with increasing age being linearly and negatively correlated with choice set size preference (Reed, Mikels & Löckenhoff, 2013). This research is seemingly at odds with Queen et al (2012) in which older and younger adults both adapted decision strategies in a similar manner when task complexity (i.e. the number of alternatives) increased. There is no simple answer for the discrepant findings although some hypotheses can be put forward. Choosing an appropriate healthcare plan (albeit in a hypothetical, laboratory, environment) may be associated with some level of stress whereas the experimental task in Queen et al. (choosing between automobiles) is likely to invoke,

relatively, a much lower level of stress. Stress has been found to negatively impinge more upon older adults' decision performance compared to younger adults (Cooper et al. 2013). Furthermore, it is worth noting that although age has been found to be a significant factor in determining decision-making performance in multi-attribute tasks, numerosity may account for greater variance in choice performance compared to age (Szrek & Bundorf, 2011; Tanius, Wood, Hanoch & Rice, 2009). Therefore, differences in numerosity between the samples in each study may account for at least part of the reason for the discrepancy. Further work, which may focus on manipulating stress and assessing decision-making performance or exploring age-independent cognitive factors that may influence performance, is required to bridge these apparent discrepant findings.

Differences in decision quality between older and younger adults in multi-attribute tasks have been associated with shifts in the heuristics used as we age. In tasks designed to assess decision-making in real-world choices such as choosing between different healthcare or retirement plans, participants were given several options which differed in the number of outcomes that each alternative "covered" and the probability of that outcome occurring (Besedeš, Deck, Sarangi & Shor, 2012<sup>a</sup>, Besedeš, Deck, Sarangi & Shor, 2012<sup>b</sup>). It was not necessarily the case that the alternative that covered the most outcomes covered the most probable outcome. Younger adults tended to focus on the probabilities associated with the occurrence of each outcome and select an outcome that was thought to have a higher chance of providing a gain, denoting a level of formulaic processing. In contrast, older adults tended to rely on a simpler heuristic, tallying, in which the alternative chosen was the one that covered the greatest number of outcomes. Under 40s chose the optimal alternative in 52% of all choices whereas in over 60s this decreased to 32% and in

over 75s this decreased further to 25% (with increasing age associated with an increase in a reliance on tallying). This decrease in decision performance, again, links back to decreased cognitive (particularly executive) function underpinned by changes in neural structure and functioning. Therefore, in terms of real-world scenarios, a “less-is-more” approach may be more suitable for the older adult decision-maker although there are questions as to how much “less” would be the correct amount, as discussed in the previous paragraph. Furthermore, the question as to who shortlists any large choice set first will, no doubt, lead to difficult debate. Again, numerosity may be an important consideration (Szrek & Bundorf, 2011; Tanius et al., 2009). Therefore, in addition to a consideration of age, assessment of numerosity would also be appropriate to identify individuals at greater risk of making non-optimal choices as regards the individual’s own status.

To summarise this section, there have been a number of choice domains in which the older adult makes a choice associated with a poorer outcome compared to the younger adult. The research has mostly focused on decisions under risk. Further work is required to identify in which exact choice scenarios negative age-related changes are apparent. Identifying these will pave the way for the creation of interventions, such as decision aids, and the integration of these into everyday life in order for decision quality to be improved.

### **Differences in neural function between older and younger adults and their association with decision-making functioning.**

Research has begun to reveal telling differences between older and younger adults in the functioning of brain areas associated with decision-making and how

these changes relate to differences in observed behaviour. This research provides targets for future research and also for research utilising decision aids to compensate for negative age-related effects on decision-making as we can assess the effectiveness of such aids in engaging cognitive processes. This field of research is emerging (for reviews published at an early stage in the development of the research field, see Brown & Ridderinkhof, 2009; Marschner et al., 2005; and Mohr, Li & Heekeren, 2009) but still in its infancy and there remain a multitude of avenues of research that require exploration.

Despite older adults engaging the same network of brain areas associated with decision-making as those reliably seen in younger adults (Elliott, Friston & Dolan, 2000; Labudda et al., 2008; Rogalsky et al., 2012; Robbins & Everitt, 1996), there are notable changes within this system that can be linked to changes in outward decision-making behaviour that have been reviewed earlier. Predominantly, the literature has explored neural activity associated with choices involving risky monetary rewards (typically hypothetical). As can be noted from the literature reviewed so far there are reliable findings regarding age-related changes in the quality of risky decision-making. Age-related changes in decisions involving risk have been found to be underpinned by functional changes to particular regions of the brain involved in reward processing and emotion. In choices between a certain, small, reward and a risky but larger reward older adults (mean age 65.2 +/- 4.2 years) tend to favour the safer alternative compared to younger (mean age 29.9 +/- 6.2 years) adults (Lee, Leung, Fox, Gao & Chan, 2008). In this task, consistent choice of any one alternative led to the same quantity of total gain. Activity with the orbitofrontal cortex (OFC) was increasingly bilateral in older vs. younger adults. The OFC has been reliably associated with risky decision-making (Jollant et al., 2010),



notably the integration of emotion into decision-making frameworks (Wallis, 2007) and has been linked to risk propensity (Zhou et al., 2014). Furthermore, older adults expressed more activity within the right insula compared to younger adults, an area involved in risk processing, notably risk aversion tendencies (Kuhnen & Knutson, 2005). On a side note, when investigating sex differences in a group of younger adults (around 30 years of age) females show a similar pattern of brain activity to the older adults and tended to make more risk aversive choices following loss-related feedback compared to males (Lee, Chan, Leung, Fox & Gao, 2009). Females tend to be risk averse compared to males (Powell & Ansic, 1997; Zhou et al., 2014) which is the same pattern of behaviour shown by older vs. younger adults. Given the role of these regions in risk aversion and decision-making, greater activation within the OFC and insula within these groups potentially underpins a general risk-averse decision-framework (Depping & Freund, 2011; Depping & Freund, 2013; Zhou et al., 2014). In older adults this risk-aversion has been linked to the positivity effect whereby neural structures involved in risk processing underlie the tendency to discount more risky alternatives in favour of gaining a higher probability of acquiring positive rewards, no matter the magnitude.

Further to differential activity in neural regions associated with the processing of risk, there is neurobiological evidence showing that the process of reward and loss valuation is different in older vs. younger adults. Activity within the ventral striatum, a region associated with representation of subjective reward value (Delgado, 2007), shows decreased function in older (62-78 years) vs. younger (19-28 years) adults when anticipating probabilistic rewards (Schott et al., 2007). Furthermore, there have been found to be age-related increases in changes in temporal variability in signalling within the ventral striatum (Samanez-Larkin, Kuhnen, Yoo & Knutson, 2010). In other

words, healthy aging is associated with an increase in “noise” within ventral striatal signalling. This noise has been linked to findings showing age-related degradation in the ability to learn stimulus-outcome links (Mell et al., 2005). Age-related changes in ventral striatal function may be particularly pronounced when anticipating losses with older adults expressing significantly blunted activity within this region compared to younger adults (Samanez-Larkin et al., 2007). Taken as a whole, there is emerging evidence to suggest that the emergence of the positivity effect is due to evolving changes within multiple regions within the decision-making system in the brain as one ages.

Reduced striatal functioning has also been linked to visible age-related changes in behaviour within another domain of decision-making, that of choosing outcomes containing delayed outcomes. Older adults typically show a greater level of self-control, i.e. are more likely to choose delayed, larger, rewards rather than using an impulsive choice strategy and selecting a smaller, immediate (or sooner), reward (Green, Fry & Myerson, 1994; Green, Myerson, Ostaszewski, 1999; Reimers, Maylor, Stewart & Chater, 2009). Only one study has explored the possible neurobiological basis for this age-related shift in choice dynamics. In this study, decreased ventral striatal activity was again found in older (65-80 years, CD) vs. younger (18-28 years, US) adults (Eppinger, Nystrom & Cohen, 2012). Increased ventral striatal activity has been associated with impulsive choice behaviour (Buckholtz et al., 2010; Cools, Sheridan, Jacobs & D’Esposito, 2007) thus decreased function within the older adults would lead to the observed increase in self-controlled choice, indicating that age-related changes in neurobiological function can have dramatically different effects within the domain of decision-making.

As was noted earlier, the vast majority of the literature has explored decision-making when money is at stake. Much less attention has been directed to social decision-making. This review has already covered reliable findings showing that older adults tend to focus more on intrinsic, and personally/socially rewarding gains, gains as compared to younger adults who focus more on extrinsic, typically financial, gains. Thus, exploring social decision-making in the older adult is pertinent. A common experimental task used to explore social decision-making is the ultimatum game. In the ultimatum game a proposer is given a (typically hypothetical) small amount of money (e.g. \$10) of which he/she is asked to share any unit value of which with another player called the receiver (e.g. keep \$6, share \$4). The receiver then chooses whether to accept the shared amount of money. If the offer is accepted both players receive the proposed share. If the receiver does not choose to accept, both players receive nothing. Older adults (age 55-78 years,  $M = 64.1$  years) are significantly more likely to reject moderately unfair offers (i.e. share \$3) than younger adults (18-27 years,  $M = 22.4$  years) and have a greater expectation that offers should be equitable (Harlé & Sanfey, 2012), especially so in those older adults who report greater levels of emotional empathy (Beadle et al., 2012). When receiving unfair offers older adults express more activation of the dorsolateral prefrontal cortex compared to younger adults. The dorsolateral prefrontal cortex plays a large role in executive functioning (Miller & Cohen, 2001). It was suggested that greater activity in this region is associated with increased engagement of computational rule usage. Furthermore, older adults express comparatively less activity in the anterior insula. In social situations, activation of the insula has been associated with violation of social norms by a third-party (Sanfey, Rilling, Aronson, Nystrom & Cohen, 2003). Decreased activity in this area within older adults has been attributed to the positivity

effect, whereby norm violation is processed to a lesser extent in older than younger adults (Harlé & Sanfey, 2012). This finding is potentially contrasting that of Lee et al. (2008) that found increased insula activity during a risky decision-making task; however, these two tasks are exploring different processes with one investigating choices between two well-defined rewards and the other exploring social interaction.

This section has reviewed the neurobiological literature that has indicated that healthy aging is associated with changes in function in key parts of the decision-making network within the brain, notably in areas involved in emotion, learning and representation of reward value. A significant amount of further research in this area is needed to fully document how healthy aging is associated with changes in neurobiological function and, critically, linking biological changes with behavioural changes. This knowledge will lead to an increased understanding of the older adult's brain and how interventions may be put in place to bypass age-related negative changes in decision-making functioning.

## **Conclusions**

Research exploring age-related changes in decision-making is sparse relative to that within other areas, such as memory and attention. This is surprising given the significant changes that occur to decision-making functioning as we age. Given the ongoing trend for greater life expectancy, longer working lives and increased expectation on older adults to manage their own lives, there is a clear need for greater attention being directed toward this area of research. The findings within this field will have significant and wide impact upon our understanding of age-related changes on decision-making and how individuals and society can adapt positively to

these changes. This review has documented several decision-making domains where older adults make better decisions than younger adults, notably in areas where older adults can employ wisdom. However, the vast majority of research has explored instances of age-related degradation in decision-making quality, of which many have been documented. This review has put forward evidence suggesting that the same changes in neurobiological function within the decision-making system underlie both positive and negative age-related changes in decision-making but the direction of effect (positive or negative) depends upon particular attributes of the choice and the choice environment. Although this review has begun to identify in exactly which decision scenarios age-related negative and positive (or no) changes would be expected, further exploration of domain-specific effects is required to provide a fuller account of age-related changes to decision-making functioning. Finally, it is worthwhile bearing in mind that negative changes may be easily reversible with simple interventions although the evidence remains tentative. Much more research is required in this area, which will have huge implications for the older adult in their everyday lives and, more broadly, for society as a whole.

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